Introduction for Instructor:

This activity is designed to provide hands on measurements of ground level visible light intensity and thermal emissions from various surfaces on a campus. These measurements can, in additional activities, be used to develop an understanding of remote sensing data designed to evaluate Earth’s energy budget and the local effects of the built environment, particularly the urban heat island effect.

Albedo is calculated from measured light intensity, in units of lux (1Lux = 0.001496 W/m2), as the ratio of visible light emissions from any surface divided by the same emissions from a piece of aluminum foil.

Students are asked to evaluate the relationship between the IR temperature of the surfaces and the albedo of surfaces. In an ideal setting 1- albedo = IR emission energy. However, additional factors such as the emissivity of the surface, depth, heat and properties of the materials measured make this a less than perfect fit to the equation. In particular, water gives various results depending on its depth and the degree of disturbance in its surface.

Other factors that may affect this relationship include changing cloud cover, shading of surfaces, differences in thickness and air or water content of the same surfaces.

Previous Background

Previous discussion of basic light, the nature the electromagnetic energy and the electromagnetic spectrum as well heat transfer concepts (convection, conduction, radiation) would be necessary for full appreciation of this activity. Some familiarity with the Greenhouse Effect would enhance understanding.

Following this activity, students could be asked to relate albedo, IR emissions and temperature to the Urban Heat Island effect and to remote sensing long and short-wave radiation data (eg. CERES collected data).

Student Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Partners \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Background

The climate of the Earth and its average surface temperature is primarily determined by the amount of incoming solar radiation that reaches the Earth and its atmosphere and by the way in which that energy is absorbed and reflected. In order to maintain a relatively stable average temperature, the amount of incoming radiation needs to be roughly equal to the amount of outgoing radiation.

There are two related parts to this activity. One takes place indoors while the others involves measurements out of doors.

Part I. ALBEDO: Reflectivity of Light

(*adapted from Vernier PSV-23-COMP-reflectivity of light*)

Light is reflected differently from various surfaces and colors. An understanding of these differences is useful in choosing colors and materials for clothing, in choosing colors for cars, and in city planning. Astronomers use reflectivity differences to help determine characteristics of planets.

The light reflected from objects in the atmosphere, like clouds and airborne particles, and from the surface of the Earth, has a net cooling affect on the atmosphere. Solar energy, in the form of light, is absorbed by the atmosphere and surfaces on Earth. The energy absorbed is emitted by those surfaces as thermal energy. Ideally, the incoming radiation from the sun and the outgoing thermal energy from the Earth and its atmosphere will in balance in order to maintain a constant climate on Earth.

In this experiment, you will be measuring the ratio of reflected visible radiation to that of incoming visible radiation (albedo) from various surfaces on the ground. Keep in mind that a considerable quantity solar radiation has already been reflected and absorbed by the atmosphere.

You will measure reflection values from papers of various colors using a Light Sensor and then compare these values to the reflected visible light from aluminum foil. The aluminum foil will arbitrarily be assigned a reflectivity of 1 (100 %). Albedo for each surface is calculated from:

***albedo = lux for surface /lux for aluminum foil***

***Why?***

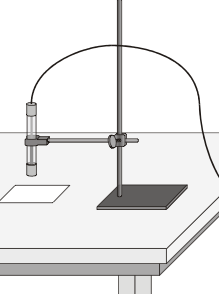
OBJECTIVES  
In this experiment, you will:

• Use a computer-interfaced Light Sensor to measure reflected light.

• Calculate the albedo various surfaces.

In Part II you will use the results of this experiment to develop a testable hypothesis about the relationship between albedo and the emitted thermal radiation from surfaces (using an IR Thermometer).

PROCEDURE

  
1. Use a utility clamp and ring stand to fasten a Light Sensor 5 cm from and perpendicular to a piece of colored paper as shown in Figure 1.

2. The Light Sensor should be set on the 0–6000 lux position. The classroom lights should be on.

3. Connect the Light Sensor to the data collection system (eg. computer)

4. When the reading stabilizes, record the color and the reflected light value (in lux). The lux is the SI unit for light illumination.

*Figure 1. Light Sensor set up.*

5. Make and record readings for aluminum, black, white, and two other colors.  
  
DATA

|  |  |
| --- | --- |
| **Color** | **Visible Light Reflected (lux)** |
| Aluminum |  |
| Black |  |
| White |  |
| Other |  |

PROCESSING THE DATA

1. Calculate the ratio of reflectivity (albedo) of each color using the formula given in the introduction. Show your work and record the results in the table below.

|  |  |
| --- | --- |
| **Color** | **Reflectivity Ratio (albedo)** |
| Aluminum |  |
| Black |  |
| White |  |
| Other |  |

2. Which color, other than aluminum, has the highest reflectivity?

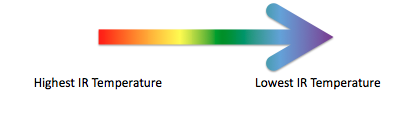
3. Which color has the lowest reflectivity?

4. Extrapolating from these results, what materials might give a city or planet a high reflectivity or albedo? Explain.

5. Does the planet Earth have high reflectivity? Explain your answer and be sure to cite a reliable Internet sources you may have used to develop your answer?

Part II. Hypothesis building and testing

Use the map of campus that is provided. Color in the main surfaces types according to how hot you would expect those surfaces to be. Use the color scale Red, Orange, Yellow, Green, Blue, Violet with red as the hottest surfaces and violet as the coolest surfaces. Discuss the colors selected for surfaces with your teammates and try to reconcile any differences.



Work with your team to develop a hypothesis about the relationship between incoming solar radiation, albedo (reflected radiation) and the emitted thermal radiation (IR temperature) from surfaces on campus.

Design an experiment to test your hypothesis with the equipment provided -

* IR thermometer,
* Visible light probe and
* Stainless steel temperature sensor.
* Aluminum foil

Once you have developed experiments to test your hypothesis begin collecting data outdoors.

Analyze your data and prepare a report on your hypothesis using the data you have collected.

Use your laboratory notebook to record your hypothesis, your experiment, the data collected and identify any calculations used to analyze the data.

Report your findings in a final lab report using standard lab report format.

A suggested table for your data:

**CAMPUS MEASUREMENTS**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SURFACE | VISIBLE LIGHT REFLECTED (lux) | ALBEDO | TEMPERATURE  (°C) | EMITTED IR RADIATION (°C) |
| Al Foil (outside) |  | 1 |  |  |
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